TRANSMISSION POWER CONTROL SYSTEM AND METHOD CAPABLE OF SAVING BATTERY CONSUMPTION OF MOBILE STATION AND PREVENTING CONNECTION CAPACITY FROM BEING REDUCED

BACKGROUND OF THE INVENTION:

This invention relates to a transmission power control system and method for use in a digital mobile communication system, in particular to a reverse-link transmission power control system of the digital mobile communication system to control reverse-link transmission power.

In the digital mobile communication system, the reverse-link (or up-link) transmission power is generally controlled to save battery consumption of mobile stations with keeping a desired receiving quality at a base station which communicate with the mobile stations and to control interference between transmission signals transmitted from the mobile stations. Especially, such transmission power control is indispensable for the code division multiple access (CDMA) system because the mobile stations simultaneously uses a common frequency band in the CDMA system. The common frequency band is also used in other cells adjoining the cell covered by the base station in the CDMA system.

A conventional transmission power control system includes a part provided in the base station and other parts provided in the base stations.

The base station has a plurality of receivers for receiving reverse-link (or up-link) transmission signals transmitted from the mobile

terminals. IF the number of the receivers is N (N: a natural number), the base station can receive N of the reverse-link transmission signals. When each of the receivers receives the reverse-link transmission signal transmitted from a certain one of the mobile terminals, it demodulates the reverse-link transmission signal to produce a demodulated signal.

The transmission power control system comprises signal-to-noise ratio (SNR) determining circuits connected to the receivers respectively in the base station. Each of the signal-to-noise ratio determining circuits determines a signal-to-noise ratio of the demodulated signal supplied from the receiver connected thereto. Herein the noise of the demodulated signal includes not only thermal noise but also interference. Accordingly, the signal-to-noise ratio is also called a signal-to-interference ratio (SIR) when attention is paid to the interference. Transmission power control (TPC) bit generators are connected to the SNR determining circuits respectively.

Each of the TPC bit generators generates a transmission power control (TPC) bit signal in response to the SNR determined by the SNR determining circuit connected thereto. The TPC bit signal is used to require the corresponding mobile station to increase of the transmission power when the SNR is smaller than a predetermined threshold. On the contrary, the TPC bit signal is used to require the corresponding mobile station to decrease of the transmission power when the SNR is larger than the predetermined threshold.

The base station multiplexes the TPC bit signal and a forward-link (or down-link) information signal for the corresponding mobile station to the corresponding mobile station.

When the corresponding mobile station receives the TPC bit signal and the forward-link information signal for the corresponding

mobile station, it controls the transmission power in response to the TPC bit signal transmitted from the base station together with the forward-link information signal for the corresponding mobile station.

Thus, the transmission power of each mobile station is controlled so that the corresponding SNR at the base station becomes larger than a desired SNR and the transmission power becomes as small as possible.

Such a transmission power control system is disclosed in Japanese Unexamined Patent Publication (JP-A) No. 8-32515.

As mentioned above, the mobile stations use the common frequency band to communicate with the base station in the CDMA system. In addition, the common frequency band is also used in other cells adjoining the cell covered by the base station in the CDMA system. Thus, increase of the mobile stations simultaneously using the common frequency band brings increase in interference between the transmission signals used in the CDMA system. When the interference becomes large, the conventional transmission power control system goes on repeating that it produces the transmission power control bit signals which require the corresponding mobile stations to increase the transmission power. As a result, a large number of the mobile stations using the common frequency band transmit the transmission signals with the maximum transmission power. Accordingly, the interference is not suppressed, rather, becomes larger. In this situation, each of the mobile stations wastes electricity of a battery on trying to improve the SNR at the base station. In addition, the maximum number of the mobile stations, which can simultaneously use in the mobile communication system, becomes small because of the interference between the cells. In other words, a connection capacity of the mobile

communication system becomes small because of the interference between the cells.

SUMMARY OF THE INVENTION:

It is therefore an object of this invention to provide a transmission power control system which is capable of detecting a situation that a desired SNR of a received signal can not be obtained at a base station by increase of transmission power of a mobile station which transmits the signal.

It is another object of this invention to provide a transmission power control system which is capable of saving vain battery consumption of a mobile station.

It is still another object of this invention to provide a transmission power control system which is capable of increasing a connection capacity of a mobile connection system.

Other object of this invention will become clear as the description proceeds.

According to a first aspect of this invention, a base station of a mobile communication system which adopts a transmission power control system comprises a communication monitor circuit to detect quality deterioration of radio communication between the base station and mobile stations. The communication monitor circuit comprises a monitor unit for monitoring a communication state of the radio communication. A judging unit is connected to the monitor unit to judge whether the communication state monitored by the monitor unit is worse than a predetermined state. A notifying unit is connected to the judging unit to notify an external circuit of the quality deterioration when the judging unit judges that the communication state is worse than the

predetermined state.

According to a second aspect of this invention, a base station of a mobile communication system which adopts a transmission power control system to control transmission power of mobile stations by use of transmission power control bit signals includes receivers for demodulating transmission signals transmitted from the mobile stations to produce demodulated signals. Signal-to-noise ratio determining circuits are connected to the receivers respectively to determine signal-to-noise ratios of the demodulated signals. Transmission power control bit generators are connected to the signal-to-noise ratio determining circuits respectively to generate the transmission power control bit signals on the basis of the signal-to-noise rations. The base station comprises a communication state monitor circuit which is connected to the receivers to detect quality deterioration of a communication state of radio communication between the base station and the mobile stations. A transmission power bit adjusting circuit is connected to the quality deterioration detector and the transmission power control bit generators to control the transmission power control bit signals so as to suppress increase of transmission power of the mobile stations when the quality deterioration detector detects the quality deterioration.

According to a third aspect of this invention, a transmission power control system is for use in a base station of a mobile communication system to control transmission power of mobile stations by use of transmission power control bit signals. The base station includes receivers for demodulating transmission signals transmitted from the mobile stations to produce demodulated signals. Signal-to-noise ratio determining circuits are connected to the receivers respectively to determine signal-to-noise ratios of the demodulated

signals. Transmission power control bit generators are connected to the signal-to-noise ratio determining circuits respectively to generate the transmission power control bit signals on the basis of the signal-to-noise rations. The transmission power control system comprises a communication state monitor circuit connected to the receivers to detect quality deterioration of a communication state of radio communication between the base station and the mobile stations. A transmission power bit adjusting circuit is connected to the quality deterioration detector and the transmission power control bit generators to control the transmission power control bit signals so as to suppress increase of transmission power of the mobile stations when the quality deterioration detector detects the quality deterioration.

According to a fourth aspect of this invention, a method of controlling transmission power of mobile stations from a base station of a mobile communication system, comprising the steps of monitoring, with a monitor unit located in the base station, a communication state of the radio communication, judging, with a judging unit connected to the monitor unit in the base station, whether the communication state monitored at the monitoring step is worse than a predetermined state, and notifying, from a notifying unit connected to the judging unit in the base station, an external circuit of the quality deterioration when judgement that the communication state is worse than the predetermined state is made at the judging step.

According to a fifth aspect of this invention, a method of controlling transmission power of mobile stations of a mobile communication system by use of transmission power control bit signals transmitted from a base station, the base station including receivers for demodulating transmission signals transmitted from the mobile stations

to produce demodulated signals, signal-to-noise ratio determining circuits connected to the receivers respectively for determining signal-to-noise ratios of the demodulated signals and transmission power control bit generators connected to the signal-to-noise ratio determining circuits respectively for generating the transmission power control bit signals on the basis of the signal-to-noise rations, comprising the steps of detecting, with a communication state monitor circuit, quality deterioration of a communication state of radio communication between the base station and the mobile stations, and controlling, with a transmission power control bit adjusting circuit connected to the communication state monitor circuit and the transmission power control bit generators, the transmission power control bit signals so as to suppress increase of transmission power of the mobile stations when the quality deterioration is detected at the detecting step.

BRIEF DESCRIPTION OF THE DRAWING:

Fig. 1 is a block diagram of a mobile communication system adopting a conventional transmission power control system;

Fig. 2 is a flowchart for describing an operation of a base station of the mobile communication system of Fig. 1;

Fig. 3 is a flowchart for describing an operation of a mobile station of the mobile communication system of Fig. 1;

Fig. 4 is a block diagram of a mobile communication system adopting a transmission power control system according to a first embodiment of this invention;

Fig. 5 is a flowchart for describing an operation of a base station of the mobile communication system of Fig. 4;

Fig. 6 is a flowchart for describing an operation of a communication state monitor used in the mobile communication system of Fig. 4;

Fig. 7 is a flowchart for describing an operation of a transmission power control bit adjusting circuit used in the mobile communication system of Fig. 4;

Fig. 8 is a block diagram of a mobile communication system adopting a transmission power control system according to a second embodiment of this invention;

Fig. 9 is a flowchart for describing an operation of a communication state monitor used in the mobile communication system of Fig. 8;

Fig. 10 is a block diagram of a mobile communication system adopting a transmission power control system according to a third embodiment of this invention;

Fig. 11 is a flowchart for describing an operation of a communication state monitor used in the mobile communication system of Fig. 10;

Fig. 12 is a flowchart for describing an operation of a communication state monitor used in a mobile communication system according to a fourth embodiment of this invention;

Fig. 13 is a block diagram of a mobile communication system adopting a transmission power control system according to a fifth embodiment of this invention; and

Fig. 14 is a flowchart for describing an operation of a transmission power control bit adjusting circuit used in the mobile communication system of Fig. 13.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

Referring to Figs. 1 through 3, description will be at first directed to a conventional transmission power control system for a better understanding of this invention.

The conventional transmission power control system is applied to a mobile communication system adopting CDMA system. The mobile communication system comprises base stations and mobile stations. Hereinafter, the description is made about one of the base stations for convenience of explanation. In Fig. 1, the base station 10 comprises receivers 11-1 to 11-N. Decoders 12-1 to 12-N are connected to the receivers 11-1 to 11-N respectively. Signal-to-noise (SNR) determining circuit 13-1 to 13-N are also connected to the receivers 11-1 to 11-N respectively. Transmission power control (TPC) bit generators 14-1 to 14-N are connected to the TPC bit generators 14-1 to 14-N. Multiplexers 15-1 to 15-N are connected to the TPC bit generators 14-1 to 14-N respectively. A transmitter 16 is connected to all of the multiplexers 15-1 to 15-N. A combination of the SNR determining circuit 13-1 to 13-N and the TPC bit generators 14-1 to 14-N serves as a part of the conventional transmission power control system.

The base station can simultaneously communicate with N (N: a natural number) of the mobile stations located in a cell covered by the base station. This is because the number of the receivers 11-1 to 11-N is N. Hereinafter, it is assumed that N of the mobile stations simultaneously communication with the base station. Additionally, the description is mainly made about an n-th ($1 \leqq n \leqq N$) mobile station, because the mobile stations have the same structure and operations.

The n-th mobile station 20-n comprises a receiver 21-n. A decoder 22-n connected to the receiver 21-n. A transmission power

control (TPC) bit decoder 23-n is also connected to the receiver 21-n. A transmission power deciding circuit 24-n is connected to the bit decoder 23-n. A transmitter 25-n is connected to the transmission power deciding circuit 24-n. A combination of the TPC bit decoder 23-n and the transmission power deciding circuit 24-n serves as another part of the conventional transmission power control system.

Referring to Figs 2 and 3, an operation of the mobile communication system will be mentioned soon.

In the base station, the receiver 11-n selectively receives a reverse-link (or up-link) transmission signal transmitted by the mobile station 20-n and demodulates it to produce a demodulated reverse-link transmission signal (Step S201). The receiver 11-n supplies the demodulated reverse-link transmission signal to both of the decoder 12-n and the SNR determining circuit 13-n.

The decoder 12-n decodes the demodulated reverse-link transmission signal into a decoded reverse-link signal as a reverse-link information signal. Because the decoded reverse-link signal is unimportant for this invention, nothing will be made about processing for the decoded reverse-link signal in below.

The SNR determining circuit 13-n determines a signal-to-noise ratio (SNR) of the demodulated reverse-link transmission signal and supplies a SNR signal representing the determined SNR to the TPC bit generator 14-n (Step S202).

The TPC bit generator 14-n finds a difference between the determined SNR determined by the SNR determining circuit 13-n and a desired SNR memorized therein to generate a transmission power (TPC) bit signal (Step S203). When the determined SNR is smaller than the desired SNR, the TPC bit generator 14-n generates a first TPC

bit signal as the TPC bit signal on the basis of the difference to require the mobile station 20-n to increase its transmission power. Conversely, when the determined SNR is larger than the desired SNR (or the higher threshold), the TPC bit generator 14-n generates a second TPC bit signal as the TPC bit signal on the basis of the difference to require the mobile station 20-n to decrease the transmission power. The TPC bit generator 14-n supplies the TPC bit signal to multiplexer 15-n.

The multiplexer 15-n multiplexes the TPC bit signal with an encoded forward-link information signal for the mobile station 20-n to produce a multiplexed signal. Generally, error-correcting code is used for the encoded forward-link information signal to correct bit errors caused in a transmission line. The multiplexer 15-n supplies the multiplexed signal to the transmitter 16 (Step S204).

The transmitter 16 multiplexes the multiplexed signal supplied from the multiplexer 15-n and other multiplexed signal the remaining multiplexer 15-1 to 15-N by the use of a code division multiplex to produce a forward-link (or down-link) transmission signal. The transmitter 16 transmits the forward-link transmission signal to the mobile stations 20-1 to 20-N.

The mobile station 20-n receives the forward-link transmission signal. In the mobile station 20-n, the receiver 21-n demodulates the forward-link transmission signal and extracts the multiplexed signal produced by the multiplexer 15-n (Step S301). The mobile station 20-n supplies the extracted multiplexed signal to both of the decoder 22-n and the TPC decoder 23-n.

The decoder 22-n extracts the encoded forward-link information signal from the extracted multiplexed signal and decodes the encoded forward-link information signal into a decoded forward-link information

signal (Step S 302). Error detection and correction is made for the decoded forward-link information signal. Because the decoded forward-link information is not important for this invention, no description will be made about processing for the decoded forward-link information signal.

On the other hand, the TPC bit decoder 23-n extracts the TPC bit signal from the extracted multiplexed signal and decodes the extracted TPC bit signal into a decoded TPC bit signal (Step S303). The TPC bit decoder 23-n supplies the decoded TPC bit signal to the transmission power deciding circuit 24.

The transmission power deciding circuit 24 decides the transmission power of the transmitter 25 in response to the decoded TPC bit signal (Step S304). However, the transmission power deciding circuit 24 restricts the transmission power under a predetermined maximum power.

The transmitter 25 transmits the reverse-link transmission signal with the decided transmission power decided by the transmission power deciding circuit 24 thereafter (Step S305).

When the number of the mobile stations, which communicate with the base station, increases, and interference between the reverse-link transmission signals of the mobile stations becomes large, the conventional transmission power control system makes the mobile stations increase the transmission power. Similarly, when interference from adjoining cells increases, the base station also makes the mobile stations increase the transmission power. In these cases, the increase of the transmission power of the mobile stations often makes the SNRs of the demodulated signals at the base station worse. The transmission power control system can not decide whether the increase

of the transmission power of the mobile station improves the SNRs of the demodulated signals or not. In addition, the mobile stations waste batteries because they transmit the reverse-link transmission signals with the maximum power in these cases. Furthermore, it makes the interference for adjoining cells large and makes connection capacity of the mobile communication system small that the mobile stations transmit the reverse-link transmission signals with the maximum power.

Referring to Figs. 4 through 7, the description will proceed to a transmission power control system according to a first embodiment of this invention. Similar parts are designated by the same reference numerals and descriptions thereof are omitted.

In Fig. 4, the transmission power control system comprises a communication state monitor 41 and a transmission power control bit adjusting circuit 42 in the base station 10.

The communication state monitor 41 is connected to the SNR determining circuits 13-1 to 13-N while the TPC bit adjusting circuit 42 is connected to the communication state monitor 41, the TPC bit generators 14-1 to 14-N and the multiplexers 15-1 to 15-N.

For the base station 10, the transmission power control system operates according a flowchart illustrated in Fig. 5.

At a step S501 of Fig. 5, the communication state monitor 41 receives the SNR signals supplied from the SNR bit determining circuits 13-1 to 13-N and decides whether a communication state between the base station 10 and the mobile stations 20-1 to 20-N keeps worse than a predetermined state for a predetermined time. When the communication state keeps worse than the predetermined state for the predetermined time, it can be considered that many of the detected SNRs are lower than the desired SNR because of the interference and

the detected SNRs can not be improved by increase of the transmission power of the mobile stations. The communication state monitor 41 notifies the TPC bit adjusting circuit 42 of quality deterioration of the communication between the base station 10 and the mobile stations 20-1 to 20-N when the communication state keeps worse than the predetermined state for the predetermined time.

Successively, the TPC bit adjusting circuit 42 adjusts the TPC bit signals supplied from the TPC generators 14-1 to 14-N according to the notification of the quality deterioration supplied from the communication state monitor 41 (Step S502). The TPC bit adjusting circuit 42 supplies the adjusted TPC bit signals instead of the TPC bit signal generated by the TPC generators 14-1 to 14-N to the multiplexers 15-1 to 15-N.

Referring to Fig. 6, the operation of the communication state monitor 41 is described in more detail. The communication state monitor 41 monitors a communication state of a radio communication between the base station 10 and the mobile stations 20-1 to 20-N as follows.

At first, the communication state monitor 41 finds averages of the determined SNRs per a predetermined time individually on the basis of the SNR signals supplied from the SNR determining circuits 13-1 to 13-N (Step S601).

Next, the communication state monitor 41 compares each of the averages with a predetermined threshold which is considerably lower than the desired SNR. Then, the communication state monitor 41 counts the number of the averages each of which is lower than the predetermined threshold. Furthermore, the communication sate monitor 41 compares the counted number with a predetermined number (Step S602).

When the counted number is equal to or lager than the predetermined number, the communication state monitor 41 judges that the communication state is worse than the predetermined state and notifies the TPC bit adjusting circuit 42 of the quality deterioration (Step S603). On the other hand, the communication state monitor 41 does nothing when the counted number is smaller than the predetermined number.

Thereafter, the communication state monitor 41 repeats the operation as shown in Fig. 6 at regular time intervals.

AS illustrated in Fig. 7, when the TPC bit adjusting circuit 42 receives the notification of the quality deterioration from the communication state monitor (Step S701), it changes the first TPC bit signals of the TPC bit signals supplied from the TPC bit generator 14-1 to 14-N into the second TPC bit signals predetermined times (Step S702). In this event, the second TPC bit signals require the mobile stations to reduce the transmission power by the fixed value regardless of the difference between the measured SNRs and the desired SNR.

Because the second TPC bit signals require the corresponding mobile stations to reduce the transmission power, the interference is suppressed. As a result, it can be avoided that the mobile stations waste batteries and that a connection capacity of the mobile communication system becomes small. Especially, in each of the adjoining cells, because the interference from the cell covered by the base station 10 is reduced, the number of the mobile stations communicating with the base station thereof becomes large.

Referring to Figs. 8 and 9, the description is made about a transmission power control system according to a second embodiment of this invention.

In Fig. 8, the transmission power control system comprising a transmission power control state monitor 81 which is connected to the TPC bit generators 14-1 to 14-N and to the transmission power adjusting circuit 42.

The transmission power control state monitor 81 operates as illustrated in Fig. 9.

At a step S901 of Fig. 9, the transmission power control state monitor 81 monitors the TPC bit signals generated by the TPC bit generators 14-1 to 14-N as the communication state. The transmission power control state monitor 81 having timers (not shown) corresponding to the TPC bit generators 14-1 to 14-N respectively. Each of the timers counts time that the corresponding TPC bit generator successively generates the first TPC bit signals as the TPC bit signal. The transmission power control state monitor 81 counts the number of the timers each of which counts a time equal to or larger than a predetermined time.

The transmission power control state monitor 81 compares the counted number of the timers with a predetermined number at a step S902.

When the counted number is equal to or larger than the predetermined number, the transmission power control state monitor 81 notifies the transmission power adjusting circuit 42 of the quality deterioration at a step 903. On the other hand, when the counted number is lower than the predetermined number, the transmission power control state monitor 81 does nothing.

Referring to Figs. 10 and 11, the description is made about a transmission power control system according to a third embodiment of this invention.

In Fig. 10, the transmission power control system comprising a transmission power control state monitor 101 which is connected to the receiver 11-1 to 11-N and to the transmission power adjusting circuit 42.

The transmission power control state monitor 101 operates as illustrated in Fig. 11.

As shown in Fig. 11, the transmission power control state monitor 101 receives the demodulated signals from the receiver 11-1 to 11-N and monitors a total electric power of interference included in the demodulated signals as the communication state (Step S1101).

Next, the transmission power control state monitor 101 compares the total electric power with a predetermined value (Step S902).

When the total electric power is equal to or larger than the predetermined value, the transmission power control state monitor 101 notifies the transmission power adjusting circuit 42 of the quality deterioration (Step S903). On the other hand, when the total electric power is lower than the predetermined value, the transmission power control state monitor 101 does nothing.

Referring to Fig. 12, the description is made about a transmission power control system according to a fourth embodiment of this invention. The transmission power control system is similar to that of Fig. 10 except for the operation of the transmission power control state monitor 101.

The transmission power control state monitor 101 operates as illustrated in Fig. 12.

As shown in Fig. 12, the transmission power control state monitor 101 receives the demodulated signals from the receiver 11-1 to 11-N. The transmission power control state monitor 101 determines not only a total electric power of interference included in the demodulated signals but also the number of the mobile stations communicating with the base

station 10 (Step S1201). Then the transmission power control state monitor 101 monitors a ratio of the total electric power to the number of the mobile stations as the communication state.

Next, the transmission power control state monitor 101 compares a changing rate of the ratio of the total electric power to the number of the mobile stations with a predetermined threshold (Step S1202).

When the changing rate is equal to or larger than the predetermined threshold, the transmission power control state monitor 101 notifies the transmission power adjusting circuit 42 of the quality deterioration (Step S1203). On the other hand, when the changing rate is lower than the predetermined threshold, the transmission power control state monitor 101 does nothing.

Referring to Figs. 13 and 14, the description is made about a transmission power control system according to a fifth embodiment of this invention.

In fig. 13, the transmission power control system comprises a TPC bit adjusting circuit 131 which is connected to the TPC bit generators 14-1 to 14-N, the multiplexers 15-1 to 15-N and the communication state monitor 41 (or 81 or 101).

The TPC bit adjusting circuit 131 operates according to a flowchart of Fig. 14.

When the TPC bit adjusting circuit 131 receives the notification of the quality deterioration (Step S1401), it reduces the desired SNRs memorized in the TPC bit generator 14-1 to 14-N (Step S1402).

The reduction of the desired SNRs decreases the transmission power of the mobile stations. Accordingly, the interference is suppressed and the batteries of the mobile stations are saved. In addition, the connection capacity of the mobile communication system

increases.

The reduction of the desired SNRs may be carried out at either all or selected some of the mobile stations. If the reduction is carried out at all of the mobile stations, it is unnecessary that the TPC bit adjusting circuit 131 receives the TPC bit signals supplied from the TPC bit generators 14-1 to 14-N. The selected mobile stations are, for example, those which generate the first TPC bit signals.

While this invention has thus far been described in conjunction with a few embodiments thereof, it will readily be possible for those skilled in the art to put this invention into practice in various other manners. For example, the transmission power of the mobile stations may be maintained when the quality deterioration is detected. This is because it is nothing that at least influence of the interference becomes large by increase of the transmission power of the mobile stations.